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Studies on Dimorphism of Spermatozoa

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STUDIES ON DIMORPHISM OF SPERMATOZOA

BY

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THESIS

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY CHARLES TIMOTHY SENAY.

ENTITLED STUDIES ON DIMORPHISM OF SPERMATOZOA.

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS.

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STUDIES ON DIMORPHISM OF SPERMATOZOA

Contents

		Page
I.	INTRODUCTION	
	1. Object of Research	1
	2. Theoretical Basis	1
	3. Listed Species having Sex Chromosomes	2
	4. Previous Work on Size Dimorphism	15
II.	MATERIAL AND METHODS	
	1. Most Desirable Species	15
	2. Fixation and Staining	16
	3. Method of Measurement	17
	4. Sources of Error	17
III.	DATA	
	Hemiptera	
	1. Leptocoris trivittatus	21
	2. Reduviolus ferus	21
	3. Corizus lateralus	22
	4. Euschistus variolarius	22
	5. Cosmopepla carnifex	24
	Coleoptera	
	6. Passalus cornutus	24
	7. Berosus striatus	25
	Annelida	
	8. Heliodrilus caliginosa	25
IV.	DISCUSSION	26
	Acknowledgments	29
V.	SUMMARY	31
VI.	BIBLIOGRAPHY OF SPERMATOGENESIS	33

I. INTRODUCTION

1. Object of Research

A limited number of cases of size dimorphism of spermatozoa has been reported. It is desirable to see if size dimorphism is a general phenomenon. Therefore the included piece of research was undertaken in the aim of determining if there was size dimorphism of spermatozoa from normal adult individuals of species hitherto unstudied.

2. Theoretical Basis

Numerous investigators have directed their attention to the problems of spermatogenesis and oogenesis as they manifest themselves in the various groups of animals. As a result of their investigations a vast amount of data has been accumulated, the large majority of which indicates that there are two kinds of spermatids in practically all species, differing quantitatively in chromatin content. This chromosomal difference proclaims itself in two ways; as the familiar unpaired "x" chromosome and as the unequal "x, y" pair of chromosomes. Modifications of these main types are found and usually arise by division of the "sex" chromosome, into more numerous units. Examples of all these variations will be found in an included list.

If, as the above evidence indicates, the chromatin content of the primitive germ cell is unequally divided in the spermatids and this division is constant within a given species, then there should be spermatozoa of two lengths in the male sexual product. Since each of these spermatozoa will be the mean of a Gaussian variation curve, a number of other lengths will be found.

A graph of the obtained results should be a combination of two normal variation curves, with two high points, indicating the two means. In cases where there has been no observed difference in the spermatids or where the female gametes possess the unequal chromatin distribution, a simple variation curve might be obtained.

In the following data "n" indicates the somatic number of autosomes. "x", or "x" and "y" indicate the sex chromosomes.

3. Listed Species having Sex Chromosomes

TYPE I. n/2, n/2 + x.

Amphibia

Alytes obstetricians. *M. = 16. **F. = 16 + x.
Janssens, F. A. P. & Willems, J. 1908.

Arachnida

Epeira sclopetaria. M. = 11. F. = 11 + x.
Berry, E. H. 1906.

Coleoptera

Anomoglossus emarginatus. M. = a. F. = a + x.
Stevens, N. M. 1906.
Chrysomela similis. M. = 11. F. = 11 + x.
Stevens, N. M. 1909.
Diabrotica. 12-punctata. M. = 9. F. = 9 + x.
Stevens, N. M. 1908a.
Diabrotica soror. M. = 9. F. = 9 + x.
Stevens, N. M. 1908a.
Diabrotica vittata. M. = 10. F. = 10 + x.
Stevens, N. M. 1908a.
Elater sp. M. = 9. F. = 9 + x.
Stevens, N. M. 1906.
Ellychnia corrusca. M. = 9. F. = 9 + x.
Stevens, N. M. 1909.
Hydrophilus piceus. M. = 15. F. = 15 + x.
Arnold, G. 1909.
Limoneus griseus. M. = 8. F. = 8 + x.
Stevens, N. M. 1909.
Necrophorus sayi. M. = 6. F. = 6 + x.
Stevens, N. M. 1909.
Photinus consanguineus. M. = 9. F. = 9 + x.
Stevens, N. M. 1909.
Photinus pennsylvanicus. M. = 9. F. = 9 + x.
Stevens, N. M. 1909.
Stenopelmatus. M. = 23. F. = 23 + x.
Stevens, N. M. 1909.

*M = male determining
**F = female determining

Corrodentia

Cerastipsocus venosus. M. = 8. F. = 8 + x.
Boring, A. M. 1913.

Echinodermata

Hipponöe esculenta. M. = a. F. = a + x.
Tennent, D. H. 1911.
Toxopneustes variegatus. M. = a. F. = a + x.
Tennent, D. H. 1912.

Hemiptera

Agallia sanguinolenta. M. = 10. F. = 10 + x.
Boring, A. M. 1907.
Alydus eurinus. M. = 6. F. = 6 + x.
Montgomery, T. H. 1906.
Alydus pilosulus. M. = 6. F. = 6 + x.
Wilson, E. B. 1905, b & c, 1906.
Amphiscepa bivittata. M. = 12. F. = 12 + x.
Boring, A. M. 1907.
Anasa armigera. M. = 10. F. = 10 + x.
Montgomery, T. H. 1906.
Anasa sp. M. = 10. F. = 10 + x.
Montgomery, T. H. 1906.
Anasa tristis. M. = 10. F. = 10 + x.
Wilson, E. B. 1905, b & c, 1906, 1907a.
Aphrophora 4 notata. M. = 13. F. = 13 + x.
Boring, A. M. 1907.
Aphrophora quadrangularis. M. = 11. F. = 11 + x.
Stevens. N. M. 1906.
Aphrophora spumaria. M. = 11. F. = 11 + x.
Boring, A. M. 1907.
Archimerus calcarator. M. = 7. F. = 7 + x.
Wilson, E. B. 1905.
Atymna castanea. M. = 10. F. = 10 + x.
Boring, A. M. 1907.
Campylenchia curvata. M. = 9. F. = 9 + x.
Boring, A. M. 1907.
Catorintha. M. = 12. F. = 12 + x.
Wilson, E. B. 1907.
Ceresa bubalus. M. = 10. F. = 10 + x.
Boring, A. M. 1907.
Ceresa diceros. M. = 10. F. = 10 + x.
Boring, A. M. 1907.
Ceresa taurina. M. = 10. F. = 10 + x.
Boring, A. M. 1907.
Chariesterus antennator. M. = 12. F. = 12 + x.
Wilson, E. B. 1909.
Chelinidea. M. = 10. F. = 10 + x.
Wilson, E. B. 1907. Morrill, C. V. 1910.
Chlorotettrix unicolor. M. = 8. F. = 8 + x.
Boring, A. M. 1907.
Chlorotetrix vividus. M. = 10. F. = 10 + x.
Boring, A. M. 1907.
Cicada tibicen. M. = 12. F. = 12 + x.
Wilcox. 1895.

Hemiptera

Clastoptera obtusa. M. = 7. F. = 7 + x.
Boring. A. M. 1907.
Corizus alternatus. M. = 6. F. = 6 + x.
Montgomery, T. H. 1906.
Corizus lateralus. M. = 6. F. = 6 + x.
Montgomery, T. H. 1906.
Corynocoris distinctus. M. = 12. F. 12 + x.
Wilson, E. B. 1909.
Diedrocephala coccinea. M. = 11. F. = 11 + x.
Boring, A. M. 1907.
Diedrocephala mollipes. M. = 11. F. = 11 + x.
Boring, A. M. 1907.
Enchenopa binotata. M. = 9. F. = 9 + x.
Boring, A. M. 1907.
Entila sinuata. M. = 10. F. = 10 + x.
Boring, A. M. 1907.
Euthoctha galeator. M. = 10. F. = 10 + x.
Wilson, E. B. 1907.
Harmostes reflexulus. M. = 6. F. = 6 + x.
Montgomery, T. H. 1901, 1906.
Hygotrechus sp. M. = 10. F. = 10 + x.
Montgomery, T. H. 1906.
Largus cinctus. M. = 5. F. = 5 + x.
Wilson, E. B. 1907, 1909, 1912.
Largus succinctus. M. = 6. F. = 6 + x.
Wilson, E. B. 1907.
Leptocoris trivittatus. M. = 6. F. = 6 + x.
Wilson, E. B. 1907.
Leptoglossus phyllopus. M. = 10. F. = 10 + x.
Wilson, E. B. 1907.
Limnotrechus marginatus. M. = 10. F. = 10 + x.
Montgomery, T. H. 1906.
Lygus pratensis. M. = 17. F. = 17 + x.
Montgomery, T. H. 1906.
Margus inconspicuus. M. = 11. F. = 11 + x.
Wilson, E. B. 1907.
Narnia. M. = 10. F. = 10 + x.
Wilson, E. B. 1907.
Oedencala dorsalis. M. = 6. F. = 6 + x.
Montgomery, T. H. 1906.
Pachylis gigas. M. = 7. F. = 7 + x.
Wilson, E. B. 1907.
Philoenus spumarius. M. = 11. F. = 11 + x.
Boring, A. M. 1907.
Phlepsius irrotatus. M. = 7. F. = 7 + x.
Boring, A. M. 1907.
Phymata sp. M. = 14. F. = 14 + x.
Montgomery, T. H. 1906.
Poeciloptera bivittata. M. = 12. F. = 12 + x.
Boring, A. M. 1907.
Poeciloptera pruinosa. M. = 13. F. = 13 + x.
Boring, A. M. 1907.

Hemiptera

Poeciloptera septentrionalis. M. = 13. F. = 13 + x.
Boring, A. M. 1907.
Protenor belfragi. M. = 6. F. = 6 + x.
Montgomery, T. H. 1901, 1906.
Pyrrochoris apteris. M. = 11. F. = 11 + x.
Henking, H. 1891. Wilson, E. B. 1907.
Vanduzea arcuata. M. = 8. F. = 8 + x.
Boring, A. M. 1907.

Myriapoda

Lithobius sp. M. = a. F. = a + x.
Blackman. 1907.
Scolopendra heros. M. = 16. F. = 16 + x.
Blackman, M. W. 1905, 1910.
Scolopendra subspinipes. M. = 16. F. = 16 + x.
Blackman, M. W. 1905, 1907.
Scutigera forceps. M. = 18. F. = 18 + x.
Medes, G. 1905.

Nematoda

Ancyracanthus cystidicola. M. = 5. F. = 5 + x.
Mulson, K. 1912.
Ascaris megalocephala. M. = a. F. = a + x.
Edwards. 1910.
Creseis acicula. M. = 9. F. = 9 + x.
Zarnik, B. 1913.
Heterakis dispar. M. = 4. F. = 4 + x.
Gulick, A. 1911.
Heterakis inflexa. M. = 4. F. = 4 + x.
Gulick, A. 1911.
Heterakis vesicularis. M. = 4. F. = 4 + x.
Gulick, A. 1911.
Strongylus paradoxus. M. = 5. F. = 5 + x.
Gulick, A. 1911.
Strongylus tenuis. M. = 5. F. = 5 + x.
Gulick, A. 1911.

Odonata

Anax junius. M. = 13. F. = 13 + x.
Lefevre, G. & McGill, C. 1908.

Orthoptera

Anabrus sp. M. = 16. F. = 16 + x.
McClung, C. E. 1902.
Aplopus mayeri. M. = 17. F. = 17 + x.
Jordan, H. E. 1908.
Arphia simplex. M. = 11. F. = 11 + x.
Carothers, E. 1913.
Arphia tenebrosa. M. = 11. F. = 11 + x.
Davis, H. S. 1908.
Blatta germanica. M. = 11. F. = 11 + x.
Morse, M. 1909.

Orthoptera

Blatta germanica. M. = 11. F. = 11 + x.
Stevens, N. M. 1906.
Brachystola magna. M. = 11. F. = 11 + x.
Sutton, W. S. 1900.
Ceuthophilus sp. M. = 18. F. = 18 + x.
Stevens, N. M. 1912.
Chortophaga viridifasciata. M. = 11. F. = 11 + x.
Davis, H. S. 1908.
Chrysochraon dispar. M. = a. F. = a + x.
Vesely, J. 1913.
Decticus verrucosus. M. = 15. F. = 15 + x.
Buchner, P. 1907.
Diestrammena marmorata. M. = 28. F. = 28 + x.
Schellenberg, A. 1913.
Dissosteira carolina. M. = 11. F. = 11 + x.
Davis, H. S. 1908. Carothers, E. 1913.
Gryllus assimilis. M. = 14. F. = 14 + x.
Baumgartner, W. J.
Gryllus campestris. M. = 19. F. = 19 + x.
Buchner, P. 1909.
Gryllus domesticus. M. = 10. F. = 10 + x.
Baumgartner, W. J. 1904.
Gryllotalpa borealis. M. = 11. F. = 11 + x.
Payne, F. 1912.
Gryllotalpa vulgaris. M. = 11. F. = 11 + x.
Vom Rath. 1892.
Hesperotettix prattensis. M. = 11. F. = 11 + x.
McClung, C. E. 1905.
Hesperotettix speciosus. M. = 11. F. = 11 + x.
McClung, C. E. 1905.
Hesperotettix viridis. M. = 11. F. = 11 + x.
McClung, C. E. 1905.
Hippiscus phoenicoptenis. M. = 11. F. = 11 + x.
McClung, C. E. 1900.
Hippiscus sp. M. = 11. F. = 11 + x.
Buchner, P. 1909.
Hippiscus tuberculatus. M. = 11. F. = 11 + x.
Davis, H. S. 1908.
Leptynia attenuata. M. = 17. F. = 17 + x.
de Sinety. 1901.
Leucophaea maderiae. M. = 11. F. = 11 + x.
Morse, M. 1909.
Locusta viridissima. M. = 16. F. = 16 + x.
Otte, H. 1906.
Melanoplus bivittatus. M. = 11. F. = 11 + x.
Nowlin, N. 1908.
Melanoplus femoratus. M. = 11. F. = 11 + x.
Davis, H. S. 1908.
Melanoplus, femur rubrum. M. = 11. F. = 11 + x.
Wilcox, E. V. 1895.
Mermiria bivittata. M. = 11. F. = 11 + x.
McClung, C. E. 1905.

Orthoptera

Micrcentra sp. M. = 16. F. = 16 + x.
McClung, C. E. 1902.

Oedipoda. F. = 11. F. = 11 + x.
Buchner, P. 1909.

Oedipoda miniata. M. = a. F. = a + x.
de Sinety, R. 1901.

Orchesticus sp. M. = 16. F. = 16 + x.
McClung, C. E. 1902.

Orphania denticauda. M. = 15. F. = 15 + x.
de Sinety, R. 1901.

Pamphagus marmoratus. M. = 9. F. = 9 + x.
Giglio, Tos. 1908.

Periplanata americana. M. = 11. F. = 11 + x.
Morse, M. 1909.

Pezotettix. M. = 11. F. = 11 + x.
Buchner, P. 1909.

Phrynotettix magnus. M. = 11. F. = 11 + x.
Pinney, E. 1908.

Psophus. M. = 11. F. = 11 + x.
Buchner, P. 1909.

Schistocerca alutacca. M. = 11. F. = 11 + x.
Hartman, F. 1913.

Schistocerca americana. M. = 11. F. = 11 + x.
Hartman, F. 1913a.

Scudderia sp. M. = 16. F. = 16 + x.
McClung, C. E. 1902.

Steiroxys trilineata. M. = 14. F. = 14 + x.
Davis, H. S. 1908.

Stenobothrus biguttulus. M. = 8. F. = 8 + x.
Gerard, Pol. 1909.

Stenobothrus curtipennis. M. = 8. F. = 8 + x.
Davis, H. S. 1908.

Stenobothrus parallelus. M. = 8. F. = 8 + x.
de Sinety, R. 1901.

Stenobothrus viridulus. M. = a. F. = a + x.
Meek, C. F. U. 1911 & 1912.

Stenopelmatus. M. = 23. F. = 23 + x.
Stevens, N. M. 1905.

Stylopyga orientalis. M. = 11. F. = 11 + x.
Morse, M. 1909.

Syrbula acuticornis. M. = 11. F. = 11 + x.
Robertson. 1908.

Syrbula admirabilis. M. = 11. F. = 11 + x.
Robertson, W. R. B. 1908.

Syrbula fusca vittata. M. = 11. F. = 11 + x.
Robertson, W. R. B. 1908.

Xiphidium fasciatum. M. = 16. F. = 16 + x.
McClung, C. E. 1902.

Vertebrata

Didelphys virginiana (opossum). M. = 8. F. = 8 + x.
Jordan, H. E. 1911.

TYPE II. n/2 + y, n/2 + x

Annelida

Tomopteris onisciformis. M. = 8 + y. F. = 8 + x.
Shreiner, A. & K. E. 1906.
Zoogonus mirus. M. = 4 + y. F. = 4 + x.
Goldschmidt, R. 1905.

Arachnida

Lycosa insopita. M. = 12 + y. F. = 12 + x.
Montgomery, T. H. 1905.

Coleoptera

Adalia bipunctata. M. = 9 + y. F. = 9 + x.
Stevens, N. M. 1909.
Blepharida rhois. M. = 15 + y. F. = 15 + x.
Stevens, N. M. 1906.
Buprestidae. M. = a + y. F. = a + x.
Stevens, N. M. 1906.
Chelymorpha orgus. M. = 10 + y. F. = 10 + x.
Stevens, N. M. 1906.
Chlaemus aestivus. M. = a + y. F. = a + x.
Stevens, N. M. 1906.
Chlaenius pennsylvanicus. M. = a + y. F. = a + x.
Stevens, N. M. 1906.
Chrysochus auratus. M. = 12 + y. F. = 12 + x.
Stevens, N. M. 1909.
Cicindela primeriana. M. = 9 + y. F. = 9 + x.
Stevens, N. M. 1906.
Cicindela vulgaris. M. = 10 + y. F. = 10 + x.
Stevens, N. M. 1909.
Coptocyda aurichalcea. M. = 10 + y. F. = 10 + x.
Nowlin, N. W. 1906.
Coptocycla clavata. M. = 8 + y. F. = 8 + x.
Stevens, N. M. 1909.
Coptocycla guttata. M. = 8 + y. F. = 8 + x.
Nowlin, N. W. 1906.
Cylene robinia. M. = 9 + y...F. = 9 + x.
Stevens, N. M. 1909.
Doryphora clivicolis. M. = 16 + y. F. = 16 + x.
Stevens, N. M. 1909.
Doryphoria decemlineata. M. = 17 + y. F. = 17 + x.
Stevens, N. M. 1906.
Epicauta cinerea. M. = 9 + y. F. = 9 + x.
Stevens, N. M. 1909.
Epicauta pennsylvanica. M. = 9 + y. F. = 9 + x.
Stevens, N. M. 1909.
Epilachna borealis. M. = 7 + y. F. = 7 + x.
Stevens, N. M. 1906.
Euchroma gigantica. M. = 12 + y. F. = 12 + x.
Nichols, M. L. 1910.
Euphoria inda. M. = 9 + y. F. = 9 + x.
Stevens, N. M. 1906.

Coleoptera

Galerita bicolor. M. = a + y. F. = a + x.
Stevens, N. M. 1906.
Haltica chalybea. M. = 10 + y. F. = 10 + x.
Stevens, N. M. 1909.
Lema trilineata. M. = 15 + y. F. = 15 + x.
Stevens, N. M. 1909.
Lina laponica. M. = 16 + y. F. = 16 + x.
Stevens, N. M. 1909.
Listotrophus cingulatus. M. = 12 + y. F. = 12 + x.
Stevens, N. M. 1909.
Obera tripunctata. M. = a + y. F. = a + x.
Stevens, N. M. 1909.
Odontota dorsalis. M. = 7 + y. F. = 7 + x.
Stevens, N. M. 1906.
Penthe obliquata. M. = 7 + y. F. = 7 + x.
Stevens, N. M. 1909.
Phytonomius punctata. M. = a + y. F. = a + x.
Stevens, N. M. 1909.
Silpha americana. M. = 19 + y. F. = 19 + x.
Stevens, N. M. 1906.
Staphylinus violaceus. M. = 21 + y. F. = 21 + x.
Stevens, N. M. 1909.
Tenebrio molitor. M. = 9 + y. F. = 9 + x.
Stevens, N. M. 1905.
Tetraopes tetraophthalmus. M. = 9 + y. F. = 9 + x.
Stevens, N. M. 1909.
Trirhabda canadense. M. = 14 + y. F. = 14 + x.
Stevens, N. M. 1906.
Trirhabda virgata. M. = 13 + y. F. = 13 + x.
Stevens, N. M. 1906.

Diptera

Anapheles pinctpennis. M. = 5 + y. F. = 5 + x.
Stevens, N. M. 1910.
Calliphora vomitoria. M. = 5 + y. F. = 5 + x.
Stevens, N. M. 1908a.
Culex pipiens. M. = 5 + y. F. = 5 + x.
Stevens, N. M. 1910.
Culex tarsilis. M. = 5 + y. F. = 5 + x.
Stevens, N. M. 1910.
Drosophila amoena. M. = 3 + y. F. = 3 + x.
Metz, C. W. 1914.
Drosophila ampelophila. M. = 3 + y. F. = 3 + x.
Stevens, N. M. 1908a.
Drosophila funebris. M. = 4 + y. F. = 4 + x.
Metz, C. W. 1914.
Drosophila quinaria. M. = 3 + y. F. = 3 + x.
Metz, C. W. 1914.
Drosophila repleta. M. = 5 + y. F. = 5 + x.
Metz, C. W. 1914.
Eristalis tenax. M. = 5 + y. F. = 5 + x.
Stevens, N. M. 1908a.

Diptera

Lucilia Caesar. M. = a + y. F. = a + x.
Stevens, N. M. 1908.
Musca domestica. M. = 5 + y. F. = 5 + x.
Stevens, N. M. 1908.
Phorbia brassica. M. = a + y. F. = a + x.
Stevens, N. M. 1908.
Sarcophaga sarraciniae. M. = 5 + y. F. = 5 + x.
Stevens, N. M. 1908a.
Scatophaga pallida. M. = 5 + y. F. = 5 + x.
Stevens, N. M. 1908a.
Tetanocera sparsa. M. = 5 + y. F. = 5 + x.
Stevens, N. M. 1908a.
Theobaldia incidens. M. = 5 + y. F. = 5 + x.
Stevens, N. M. 1910.

Hemiptera

Apiomeris crassipes. M. = 11 + y. F. = 11 + x.
Payne, F. 1912.
Banasa calva. M. = 12 + y. F. = 12 + x.
Wilson, E. B. 1907b.
Banasa dimidiata. M. = 7 + y. F. = 7 + x.
Wilson, E. B. 1907b.
Brochymena. M. = 6 + y. F. = 6 + x.
Wilson, E. B.
Calocoris rapidus. M. = 14 + y. F. = 14 + x.
Montgomery, T. H. 1906.
Coenus delius. M. = 6 + y. F. = 6 + x.
Wilson, E. B. 1905.
Cosmopepla carnifex. M. = 7 + y. F. = 7 + x.
Montgomery, T. H. 1906.
Diplocodus exsanguis. M. = 12 + y. F. = 12 + x.
Payne, F. 1909.
Enchenopa binotata. M. = 9 + y. F. = 9 + x.
Kornhauser, S. I. 1914.
Eurygaster alternatus. M. = 6 + y. F. = 6 + x.
Montgomery, T. H. 1906.
Euschistus crassus. M. = 5 + y. F. = 5 + x.
Foot & Strobell. 1912.
Euschistus fissilis. M. = 6 + y. F. = 6 + x.
Wilson, E. B. 1905. (b & c) 1906.
Euschistus ictericus. M. = 6 + y. F. = 6 + x.
Wilson, E. B. 1906.
Euschistus servus. M. = 6 + y. F. = 6 + x.
Wilson, E. B. 1905.
Euschistus tristigmus. M. = 6 + y. F. = 6 + x.
Montgomery, T. H. 1901, 1906.
Euschistus variolarius. M. = 6 + y. F. = 6 + x.
Wilson, E. B. 1906.
Lygaeus bicruris. M. = 6 + y. F. = 6 + x.
Wilson, E. B. 1912.
Lygaeus turcicus. M. = 6 + y. F. = 6 + x.
Wilson, E. B. 1905. (a & b) 1906.

Hemiptera

Metapodius (acanthocephala) femoratus. M. = 10 + y. F. = 10 + x.
Wilson, E. B. 1909.

Metapodius (acanthocephala) granulosus. M. = 10 + y. F. = 10 + x.
Wilson, E. B. 1909.

Metapodius (acanthocephala) terminalis. M. = 10 + y. F. = 10 + x.
Wilson, E. B. 1909.

Mormidea lugens. M. = 6 + y. F. = 6 + y.
Montgomery, T. H. 1906.

Nabis annulatus. M. = 8 + y. F. = 8 + x.
Montgomery, T. H. 1906.

Nezara Hilaris. M. = 6 + y. F. = 6 + x.
Montgomery, T. H. 1905. Wilson, E. B. 1910.

Nezara viridula. M. = 6 + y. F. = 6 + x.
Wilson, E. B. 1910.

Oebalus pugnax. M. = 4 + y. F. = 4 + x.
Wilson, E. B. 1910.

Oncopeltus fasciatus. M. = 7 + y. F. = 7 + x.
Wilson, E. B. 1912.

Peliopelta abbreviata. M. = 6 + y. F. = 6 + x.
Montgomery, T. H. 1906.

Peribalus limbolaris. M. = 6 + y. F. = 6 + x.
Montgomery, T. H. 1906.

Perillus confluens. M. = 6 + y. F. = 6 + x.
Montgomery, T. H. 1906.

Podissus spinosus. M. = 7 + y. F. = 7 + x.
Montgomery, T. H. 1901, 1906.
Wilson, E. B. 1906.

Poecilocapsus goniphorus. M. = 16 + y. F. = 16 + x.
Montgomery, T. H. 1906.

Rocconota annulicornis. M. = 12 + y. F. = 12 + 2x.
Payne, F. 1909.

Stiretrus anchorago. M. = 6 + y. F. = 6 + x.
Wilson, E. B. 1909.

Tingis clavata. M. = 6 + y. F. = 6 + x.
Montgomery, T. H. 1906.

Trichopepla semivittata. M. = 6 + y. F. = 6 + x.
Montgomery, T. H. 1906.

Trichopepla. M. = 6 + y. F. = 6 + x.
Wilson, E. B. 1905.

Zaitha sp. M. = 11 + y. F. = 11 + x.
Montgomery, T. H. 1906.

Nematoda

Ascaris felis. M. = 8 + y. F. = 8 + x.
Edwards. 1911.

Orthoptera.

Anisolabis maritima. M. = 11 + y. F. = 11 + x.
Randolph, H. 1908.

Forficula auricularia. M. = 11 + y. F. = 11 + x.
Stevens, N. M. 1910.
de Sinety. 1901.

TYPE III. n/2, n/2 + 2 or more x.

Arachnida

Agalena naevia. M. = 19. F. = 19 + 2x.
Wallace, L. B. 1908.
Pholcus phalangoides. M. = a. F. = a + 2x.
Wallace, L. B. 1908.
Maevia vittata. M. = a. F. = a + 2x.
Painter, T. S. 1913.

Hemiptera

Syromastes marginatus. M. = 10. F. = 10 + 2x.
Gross, J. 1904.

Nematoda

Ascaris lumbricoides. M. = 19. F. = 19 + 5x.
Edwards. 1910.

Trenatoda

Schistosomum haematobium. M. = 6. F. = 6 + 2x.
Lindner, E. 1914.

Vertebrata

Pig. M. = 10. F. 10 + 2x.
Wodsedalek, J. E. 1913.
Homo sapiens. (man) M. = 10. F. = 10 + 2x?
Guyer, M. F. 1910.
Winiwarter, H. von. 1912. M. = 23. F. = 24.

TYPE IV. n/2 + y, n/2 + 2 or more x.

Hemiptera

Acholla ampliata. M. = 10 + y. F. = 10 + 5x.
Payne, F. 1909.
Conorhinus sanguisugus. M. = 10 + y. F. = 10 + 2x.
Payne, F. 1909.
Fitchia spinosula. M. = 12 + y. F. = 12 + 2x.
Payne, F. 1909.
Gelastocoris (Galgulus) oculatus. M. = 15 + y. F. =15+4x
Payne, F. 1909.
Pnirontis modesta. M. = 10 + y. F. = 10 + 4x.
Payne, F. 1912.
Pselliodes cinctus. M. = 12 + y. F. = 12 + 3x.
Payne, F. 1912.
Prionidus cristatus. M. = 11 + y. F. = 11 + 3x.
Payne, F. 1909.
Thyanta calceata. M. = a + y. F. = a + 2x.
Wilson, E. B. 1909.
Sinea complexa. M. = 12 + y. F. = 12 + 3x.
Payne, F. 1912.
Sinea confusa. M. = 12 + y. F. = 12 + 3x.
Payne, F. 1912.

Hemiptera
Sinea diadema. M. = 12 + y. F. = 12 + 3x.
Payne, F. 1909, 1912.

Hemiptera
Sinea rileyi. M. = 12 + y. F. = 12 + 5x.
Payne, F. 1912.
Sinea spinipes. M. = 12 + y. F. = 12 + 3x.
Payne, F. 1912.

Nematoda
Ascaris lumbricoides. M. = 18 + x. F. = 18 + 5x.
Edwards, C. L. 1910.

TYPE V. n/2, n/2. (No observable difference in spermatozoa. There may or may not be a difference in the eggs.)

Amphibia
Salamandra maculosa. M. = 12. F. = 12.
Schreiner, A. & K. E. 1906b.

Coleoptera
Silpha carinata. M. = 16. F. = 16.
Holmgren, N. 1902.

Echinodermata
Asterias vulgaris. M. = 9. F. = 9.
Tennent, D. H. 1907.

Hemiptera
Brown Rose aphid. M. = 5. F. = 5.
Green Rose aphid. M. = 7. F. = 7.
Migratory Rose aphid. M. = 9. F. = 9.
Saranac Willow aphid. M. = 5. F. = 5.
Harpswell Willow aphid. M. = 3. F. = 3.
Aphis oenotherae. M. = 5. F. = 5.
Oenothera aphid II. M. = 4. F. = 4.
Black milkweed aphid. M. = 4. F. = 4.
Orange milkweed aphid. M. = 4. F. = 4.
Pale milkweed aphid. M. = 7. F. = 7.
Nasturtium aphid. M. = 4. F. = 4.
Oak aphid. M. = 7. F. = 7.
Beach goldenrod aphid. M. = 6. F. = 6.
Tall goldenrod aphid. M. = 6. F. = 6.
Paper birch aphid. M. = 9. F. = 9.
Clover aphid. M. = 8. F. = 8.
Woolly beech aphid. M. = 8..F. = 8.
Star cucumber aphid. M. = 5. F. = 5.
Maple aphid. M. = a. F. = a.
Pea aphid. M. = 4. F. = 4.
Gourni aphid. M. = 5. F. = 5.
Stevens, N. M. 1905.

Isoptera

Termopsis angusticollis. M. = 26. F. = 26.
Stevens, N. M. 1905.

Lepidoptera

Abraxas. M. = 9. F. = 9.
Wilson, E. B. 1909.
Cacoecia cerasivorana. M. = a. F. = a.
Stevens, N. M. 1906.
Euvanessa antiopa. M. = a. F. = a.
Stevens, N. M. 1906.

Mollusca

Sagitta bipunctata. M. = 9. F. = 9.
Bordas, M. 1912.

Trichoptera

Platyphylax designatus. M. = 30. F. = 30.
Lutman, B. F. 1910.

UNCLASSIFIED FORMS HAVING SEX CHROMOSOMES:

Vertebrata

Dasypus sexcinctus (armadillo)
Patterson, N. E. 1910.
Bat.
Jordan, H. E. 1913.
Bos tauris (bull)
Jordan, H. E. 1913.
Schnoenfeld, H. 1901.
Felis catus. (cat)
Saintmont, W. 1909.
Canis familiaris (dog)
Jordan, H. E. 1913.
Equus caballus (horse)
Jordan, H. E. 1913.
Guinea pig.
Stevens, N. M. 1911.
Mule.
Jordan, H. E. 1913.
Rat.
Duesberg, J. 1909.
Ovis (sheep).
Jordan, H. E. 1913.
Mus sp. (white mouse)
Jordan, H. E. 1913.

4. Previous Work on Size Dimorphism

Dr. Charles Zeleny and Mr. E. C. Faust published data and curves for fifteen species of animals in the Journal of Experimental Zoology, Volume 18, Number 2, February, 1915. Altogether they made thirty-three separate determinations. The subjects used were Musca domestica, Lygaeus kalmii, Alydus pilosulus, Anasa tristis, Trirhabda tomentosa, Phytonomus punctatus, Melanoplus femur rubrum, Melanoplus differentialis, Gryllus abbreviatus, Aeshna canadensis, Rana pipiens, Pseudemys troosti, Ovis aries, Bos taurus and Canis familiaris. Their general results indicate that the population of spermatozoa from a single testes is made up of two separate groups.

Mr. J. E. Wodsedalek published data on the pig in 1913 which indicates a bimodal curve in the spermatozoan population of this animal.

II. MATERIAL AND METHODS

1. Most Desirable Species

The best species which could be used in a piece of work of this character would be those in which the greatest chromosomal differences have been described. Such forms as Protenor belfragei, Largus cinctus and others of like nature seemed highly desirable. Forms for which figures of the chromosomes were published were also desirable, as a calculated ratio obtained from these figures would offer a standard for checking the actual ratio obtained. The lengths of the spermatozoa should vary as the cube root of the total volume of the contained chromatin.

The most desirable species were not easily obtainable inasmuch as in many cases sexual maturity occurs during the summer. Material from such species as could be found was mounted and that which was seemingly the most desirable was used in the measurements. A considerable number of insects hibernate beneath old boards, decaying bark, etc. The bases of mullein plants often harbor many guests when other places are barren of life.

Insect testes are always located in the abdomen, usually towards the tip and at the dorsal side. They are readily distinguished and are often yellow or red in color.

2. Fixation and Staining

After experimenting with Delafield, Ehrlich and Heidenhain haematoxylins it was finally decided that Heidenhain's iron haenatoxylin gave the best results. The testes were dissected in normal salt solution. The spermatozoa, taken when possible from the vas deferens, were smeared on an albumen coated slide and fixed over osmic acid fumes. After a few seconds of treatment with the osmic fumes they were allowed to just reach a dry condition, then washed in tap water and left in Heidenhain for several hours. From the Heidenhain they were dipped in tap water and left in a one half per cent solution of haematoxylin for 10-15 hours. The time factor seems to be unimportant if not too seriously abused. They were rinsed in tap water again and destained in the Heidenhain. Destaining takes about eight minutes with a fresh solution. When properly destained they were run up thru the alcohol series into xylol and mounted in balsam. In bringing the

slides over into the one-half per cent haematoxylin, a slight amount of the Heidenhain is carried also. The iron in this aids in giving a desirable intensely black stain.

3. Method of Measurement

In all the sperm heads measured, the natural form seemed to be a straight one. Many individuals were curved and twisted on the slide. Of course, only the straight ones were measured. It is necessary to accuracy that the spermatozoan be in a horizontal position. No individuals were measured, all of whose length was not visible at the same amount of focus in the microscope. Measurements were made with a No. 2 Leitz ocular, A 1/12 oil immersion objective was used. A mechanical stage obviated all danger of duplicate measurements. In practically all cases spermatozoa were measured to lengths of an ocular division. Personal errors were eliminated as far as possible by numerous remeasurements. Measurements were not made by poor light. No measurements were made when fatigue might influence the result. Care was taken to have all measurements made under as nearly the same conditions as possible. Tabulation of data was not made until the full number decided upon for the set had been completed. This was to avoid danger of a false judgment and the selection of particular values.

4. Sources of Possible Error

Before accepting the results obtained all possibilities of incorrectness must be considered. These fall into three classes: 1. Mechanical errors, those due to the personal equation of the observer or other errors of measurement. 2. Errors due

to poor methods of technique. 3. Errors due to artificial demorphism in the living material which might ensue because of the presence of any one of a number of conditions.

A. Possible Mechanical Errors

a. All spermatozoa, all of whose length was not in focus at the same time, were eliminated. It is possible that this might occur more frequently with long individuals than with short ones. This might produce asymmetry in a curve but there is no reason to believe that it would result in bimodality.

b. Each set of measurements required a number of sittings, usually twelve to fifteen. This number itself would tend to prevent bimodality resulting from possible change of standards, poor light, fatigue, etc.

c. The character of the scale might tend to cause grouping around certain points. Thick lines might obscure the nearest tenths, etc. The scale used had the narrowest lines of any obtainable. Frequent remeasurements were made and final results did not show any grouping of this kind. Many spermatozoa come nearly between two units of measurement. Biased judgment resulting from previous determinations, or an unbased hypothesis might throw these into one group more frequently than another. In plotting curves the obtained lengths were grouped by fifths while measurements were made to tenths, thus counteracting this tendency.

B. Possible Errors of Technique

a. Lack of uniformity of fixation or staining on the slide. Tabulations made by Zeleny and Faust for different regions

of the slide showed no deviation from the general dimorphism.

b. Material at the edge dries more rapidly in the process of fixation than that of the center. Tabulations by Zeleny and Faust of material of the two regions showed no essential difference between them.

c. Material drawn over a slide by means of currents set up in the suspending liquid may have smaller individuals at one end of the smear than at the other. In the preparations made, all material was equally distributed to all parts of the slide and dried in position before staining.

d. In smearing material some spermatozoa may be stretched or otherwise distorted. These are easily recognized and were always eliminated.

e. Some spermatozoa may be curved. These were never measured, only the straight individuals being used.

f. In case longer spermatozoa curved more often than shorter ones a disparity of numbers might occur. However, this would cause asymmetry rather than bimodality.

g. The chromatin rod usually takes an intense stain and the cytoplasmic cap a light one. In cases of a short cap or insufficient destaining there might be a tendency to measure to the end of the head. This would produce apparent dimorphism.

C. Errors Due to Artificial Dimorphism in the Living Material

a. Error of random sampling. The spermatozoa taken may not be representative of the mass for the entire testis. The large number of individuals measured should prevent this possibility

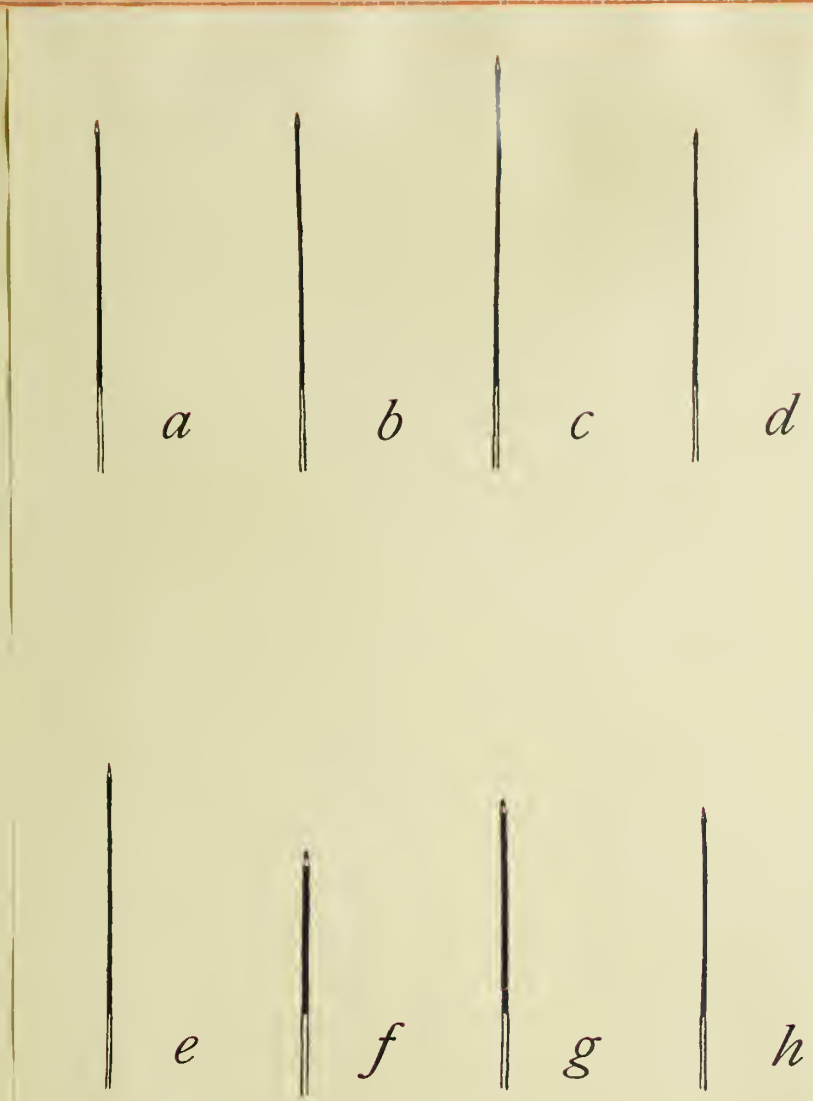
b. Two or more different degrees of maturity may be present in the material studied. This would give an apparent dimorphism. The use of material which was very active would tend to eliminate this chance. The supposition would also involve the hypothesis that there was an abrupt break in continuity between two stages of development. This seems to be hardly likely.

c. Spermatozoa of like size may congregate in masses in particular parts of the vas deferens because of similarity in physiological activity or perhaps mechanically. The entire contents of the vas deferens were suspended in a drop of physiological normal salt solution and the whole was thoroughly mixed before making smears.

d. The chromatin rod length may not be a true index of the length of the entire sperm head. As the chromatin rod represents nearly the entire length this objection is not to be considered seriously. Moreover quantitative difference in chromatin content must necessarily affect the head length of spermatozoa.

e. Spermatozoa from two different individuals might show dimorphism not due to differences present within a single testes. The fact that material used was taken from a single testis removes this difficulty.

Other sources of error might be included. Those cited are the ones regarded as most important. Nearly all these possibilities would cause asymmetry rather than bimodality. Moreover the accumulation of data, practically all of which shows bimodality, makes the supposition nearly incontrovertible that such bimodality is due to the presence of two kinds of spermatozoa differing in



Spermatozoan heads

a. Leptocoris trivittatus
b. Reduviolus ferus
c. Corizus lateralus
d. Euschistus variolarius
e. Cosmopepla carnifex
f. Passalus cornutus
g. Berosus striatus
h. Helicdrilus caliginosa

Magnification = 900

chromatin content.

D A T A

1. Leptocoris trivittatus

E. B. Wilson (1906) states that this insect has two kinds of spermatids, one containing seven and the other six chromosomes. This would put it in Type 1. No figures could be obtained. A rough comparison can be made by using the expected ratio of Anasa tristis, another coreid, as its measure.

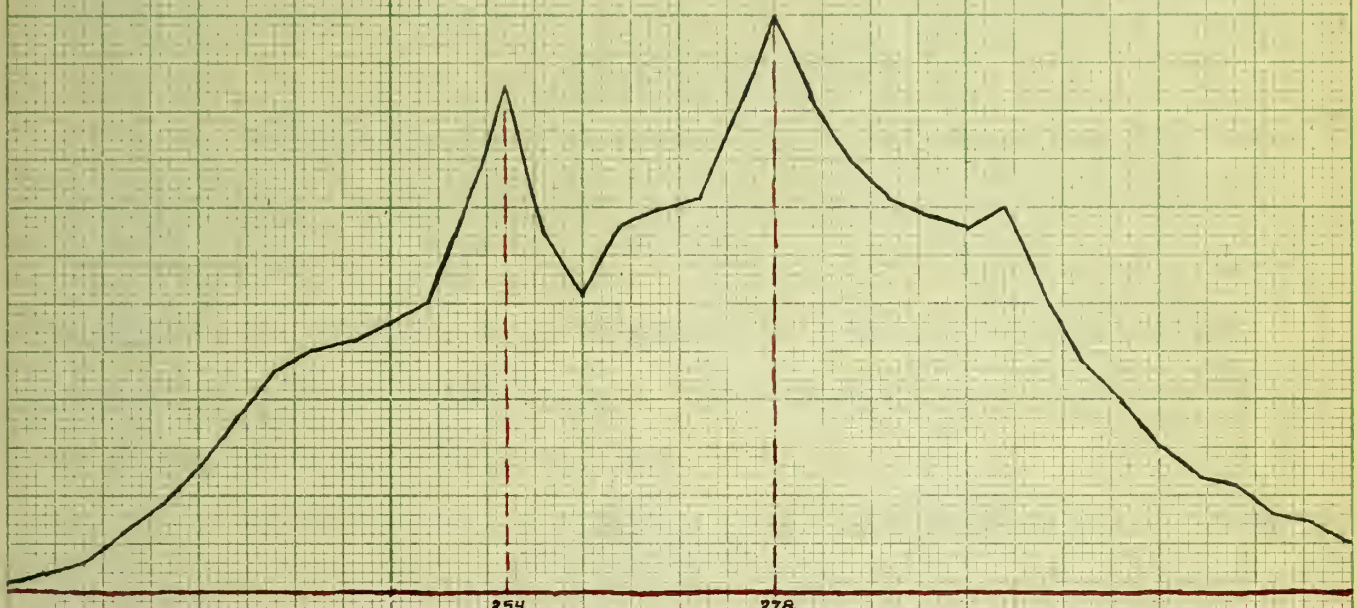
Material was obtained at Urbana in early March. One testis, only, was used and this gave an abundance of straight active spermatozoa. Nine hundred and eighty four measurements were made. One unit on the ocular micrometer scale equals 1.717 microns. The resulting curve is noticeably bimodal, the modes coming at 25.4 microns and 27.8 microns. The length ratio is 25.4:27.8 = 1:1.09. The first five hundred measurements were used as a basis for a curve and the remainder for another curve. The results were bimodal curves with modes at 25.4 and 27.8. The expected ratio of Anasa tristis is 1:1.11.

2. Reduviolus ferus

No cytological data could be obtained for this form but members of the same family have two kinds of spermatids according to T. H. Montgomery (1909).

Material was collected at Urbana about the middle of March. An abundance of active spermatozoa was taken from a single testis. This gave plenty of straight heads after fixing and staining. Five hundred measurements were made. One unit on the

LEPTOCORIS TRIVITTATUS



1. Value in microns	20.9	21.3	21.6	22.0	22.3	22.7	23.0	23.3	
Frequency	1	2	3	6	9	13	18	23	
23.7	24.0	24.4	24.7	25.0	25.4	25.7	26.1	26.4	26.7
25	26	28	30	41	53	37	31	38	40
27.1	27.4	27.8	28.1	28.4	28.8	29.1	29.5	29.8	30.1
41	50	60	51	45	41	39	38	40	31
30.5	30.9	31.2	31.6	31.9	32.3	32.6	33		
24	20	15	12	11	8	7	5		

ocular micrometer scale equals 1.717 microns. The curve indicates bimodality, but would probably be improved by the addition of a large number of measurements. The modes occur at 27.4 microns, and 28.8 microns. The head length ratio is 27.4:28.8 = 1.00:1.05.

3. Corizus lateralus

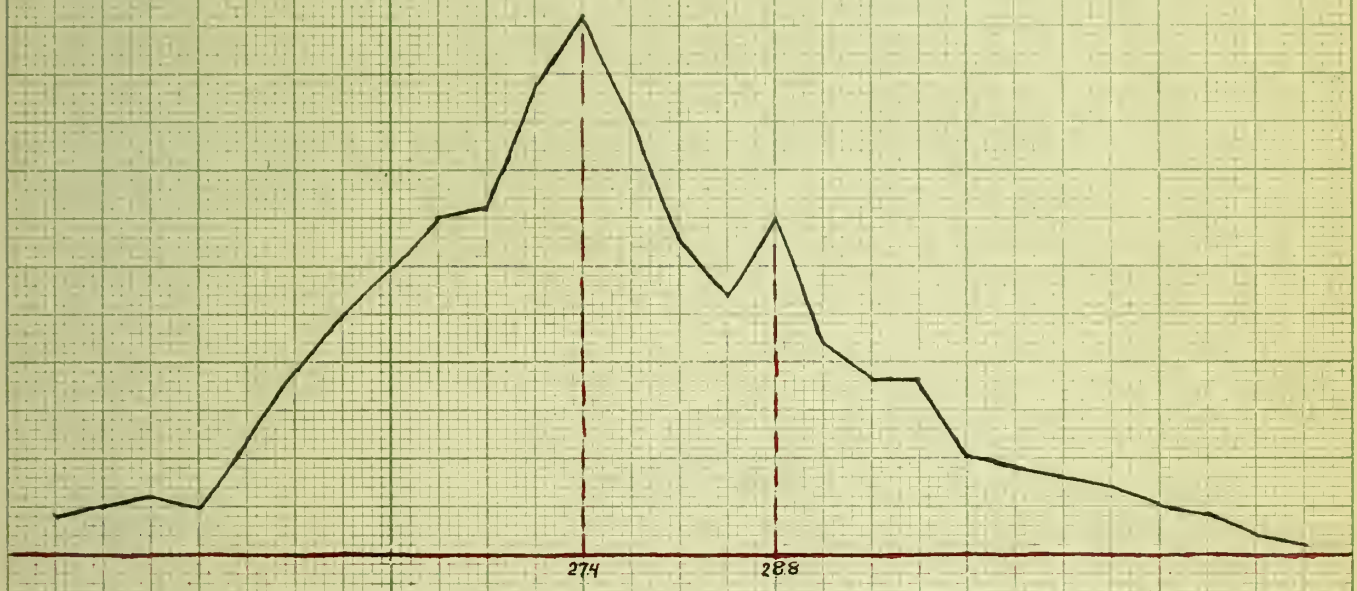
Montgomery (1906) states that this insect has two kinds of spermatids, one having six and the other seven chromosomes. This would place it in Type I. However, his figures are not large enough to be of value in determining the approximate chromatin ratio for the two spermatozoa. The expected ratio used was that of Anasa tristis, another coreid.

Material was obtained at Urbana in late March and gave an abundance of lively spermatozoa. These fixed in a satisfactory manner. Two measurements, each of five hundred individuals, were made. One division of the ocular micrometer equals 1.717 microns. The second series is a check upon the first. In both cases bimodal curves resulted. The modes were alike coming at 27.1 microns and 29.5 microns. The head length ratio is 27.1:29.5 = 1:1.09. The expected ratio, that of Anasa tristis is 1:1.11. This is probably a trifle high as Anasa tristis has an exceptionally large "x" chromosome.

4. Euschistus variolarius

Wilson (1906) demonstrates that there are two kinds of spermatids. The male producing ones have six normal chromosomes plus a small "y" shromosome and the female producers have six normal chromosomes plus an "x" chromosome. This would place the

REDUVIOLUS FERUS



2.

Value in microns	23.7	24.0	24.4	24.7	25.0	25.4	25.7
Frequency	4	5	6	5	12	19	25

26.1	26.4	26.7	27.1	27.4	27.8	28.1	28.4	28.8
30	35	36	49	56	45	33	27	35

29.1	29.5	29.8	30.1	30.5	30.9	31.2	31.6	31.9
22	18	18	10	9	8	7	5	4

32.3	32.6
2	1

3. Value in microns I. 23.0 23.3 23.7 24.0 24.4 24.7

Frequency 7 8 10 13 13 13

25.0 25.4 25.7 26.1 26.4 26.7 27.1 27.4 27.8 28.
13 14 16 19 23 27 42 30 15 11

28.4 28.8 29.1 29.5 29.8 30.1 30.5 30.9 31.2 31.
13 19 26 38 28 20 17 11 10 8

31.9 32.3 32.6
6 9 5

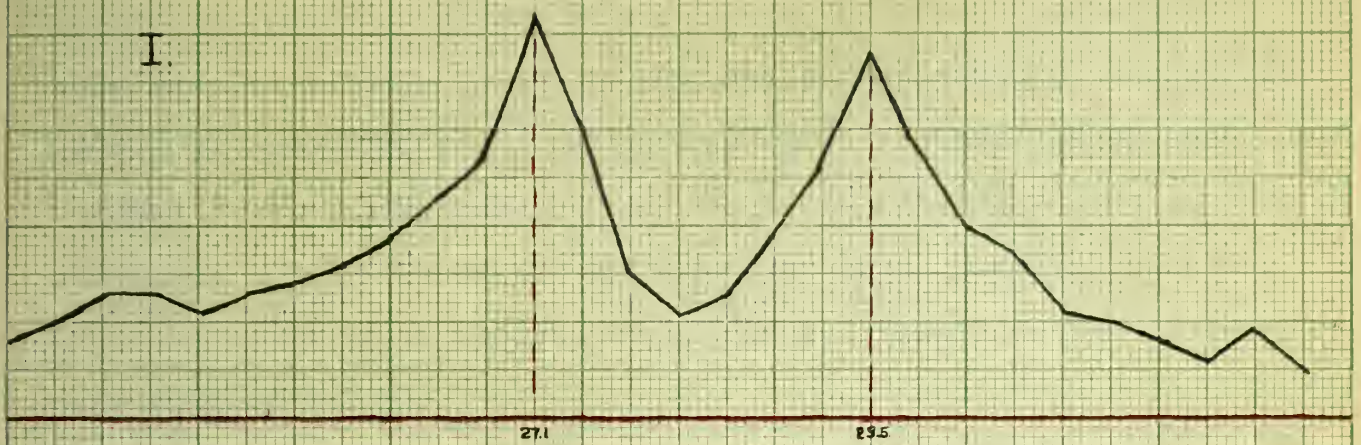
II. 23.0 23.3 23.7 24.0 24.4 24.7 25.
4 6 7 7 5 7 11

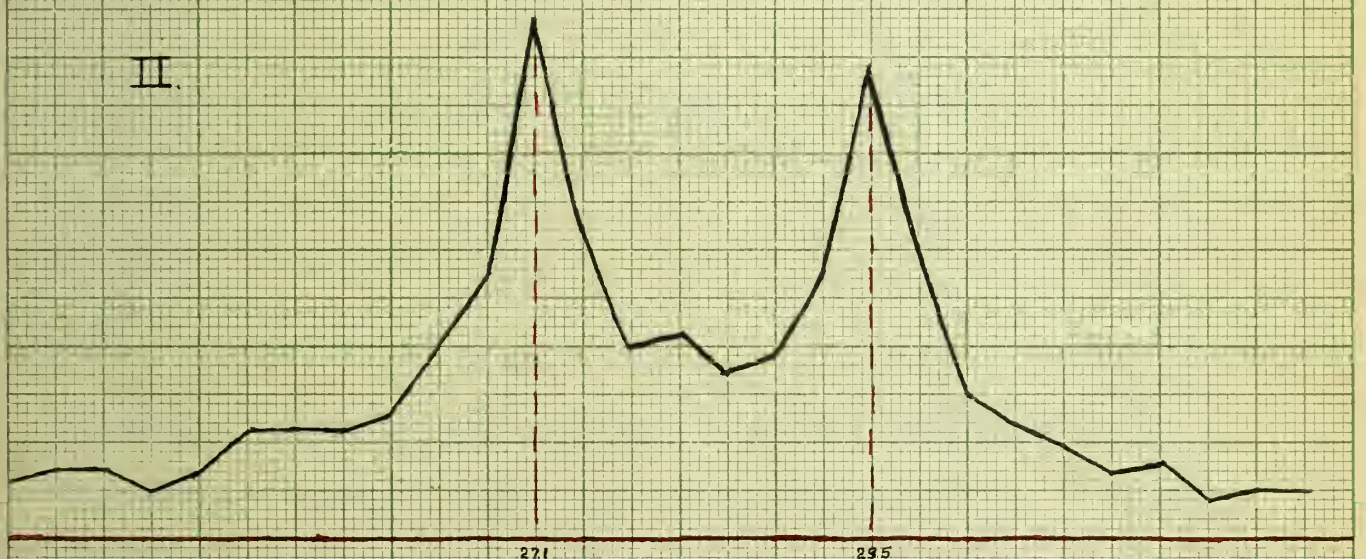
25.4 25.7 26.1 26.4 26.7 27.1 27.4 27.8 28.1 28.
11 11 13 20 27 54 32 20 21 17

28.8 29.1 29.5 29.8 30.1 30.5 30.9 31.2 31.6 31.
19 28 45 30 15 12 10 7 8 4

32.3 32.6
5 5

CORIZUS LATERALUS





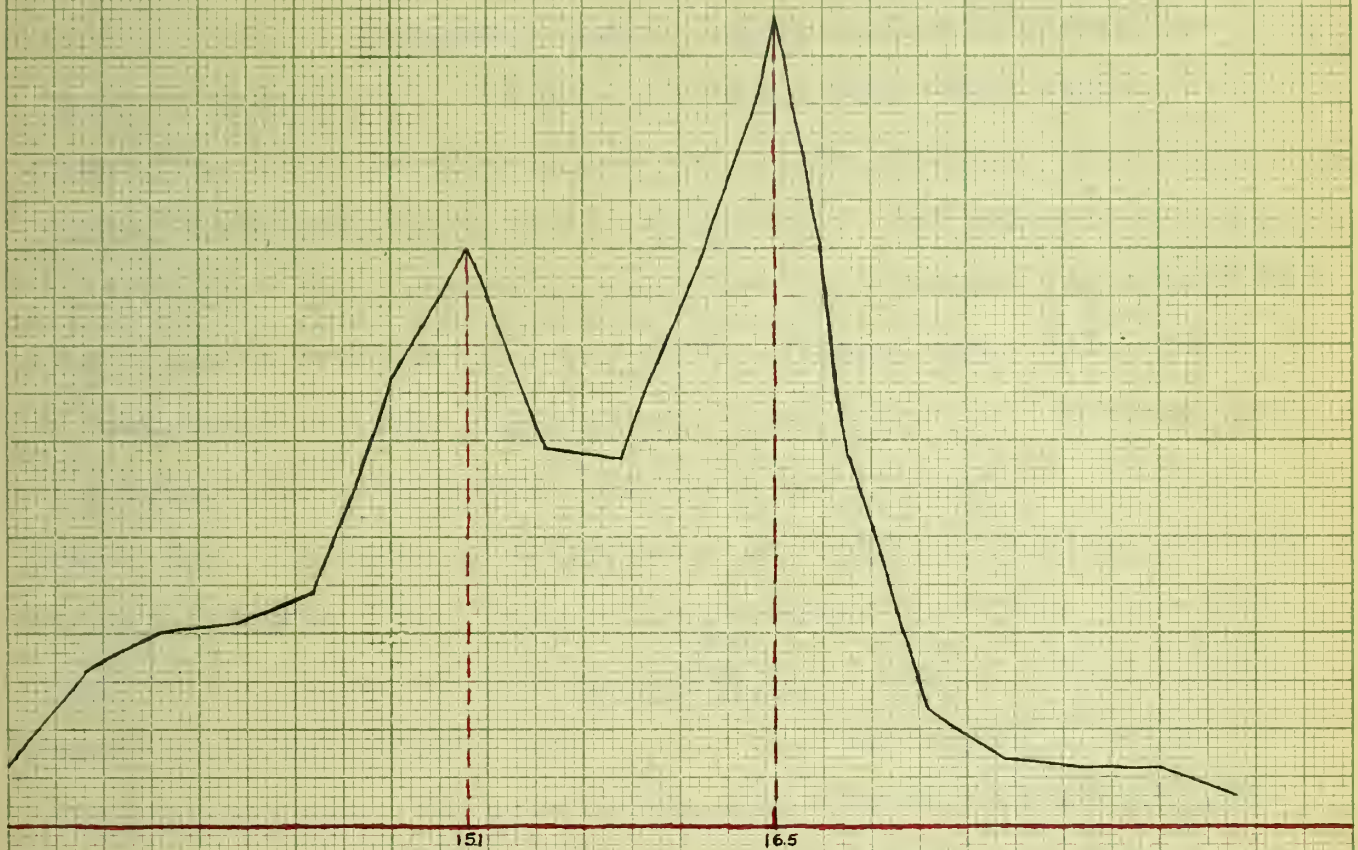
insect in Type II. Wilson gives figures of the chromosomes of this species on page 15 of the Journal of Experimental Zoology for 1906. By computing their columes as cylinders the sum of the volumes of the chomosomes of the two kinds of spermatozoa may be obtained. The ratio of the cube root of these sums will be the expected ratio of the spermatozoan heads. Length varies as the cube root of volume.

Chromosome	Width	Length	Volume
a	2.8	3.1	19.085
b	2.5	3.7	18.16
c	2.6	4.0	21.24
d	2.8	4.3	26.48
e	2.2	3.0	11.41
f	1.9	2.1	5.95
x	1	1	0.79
x	2.4	2.4	10.86

Chromatin volume of male producing spermatozoan = 103.1104.
Chromatin volume of female producing spermatozoan = 113.1824.
Calculated ratio = 1.00:1.04.

Material was obtained in Urbana about the middle of April. There was evidence that all of the spermatozoa were not fully developed. This necessitated careful selection in making measurements so as not to include unripe ones. These latter are distinguishable by their thickness and less definite outlines. Five hundred measurements were made. One division of the ocular micrometer equals 1.717 microns. The resulting curve is

EUSCHISTUS VARIOLARIUS



4.

Value in microns	13.0	13.4	13.7	14.1	14.4	14.7	15.1
Frequency	6	16	20	21	24	46	60

15.5	15.8	16.1	16.5	16.8	17.2	17.5	17.9	18.2
39	38	58	84	38	12	7	6	6

18.5
3

conspicuously bimodal. The modes come at 15.1 microns and 16.5 microns. The head langth ratio is 15.1:16.5 = 1:1.09

5. Cosmopepla carnifex

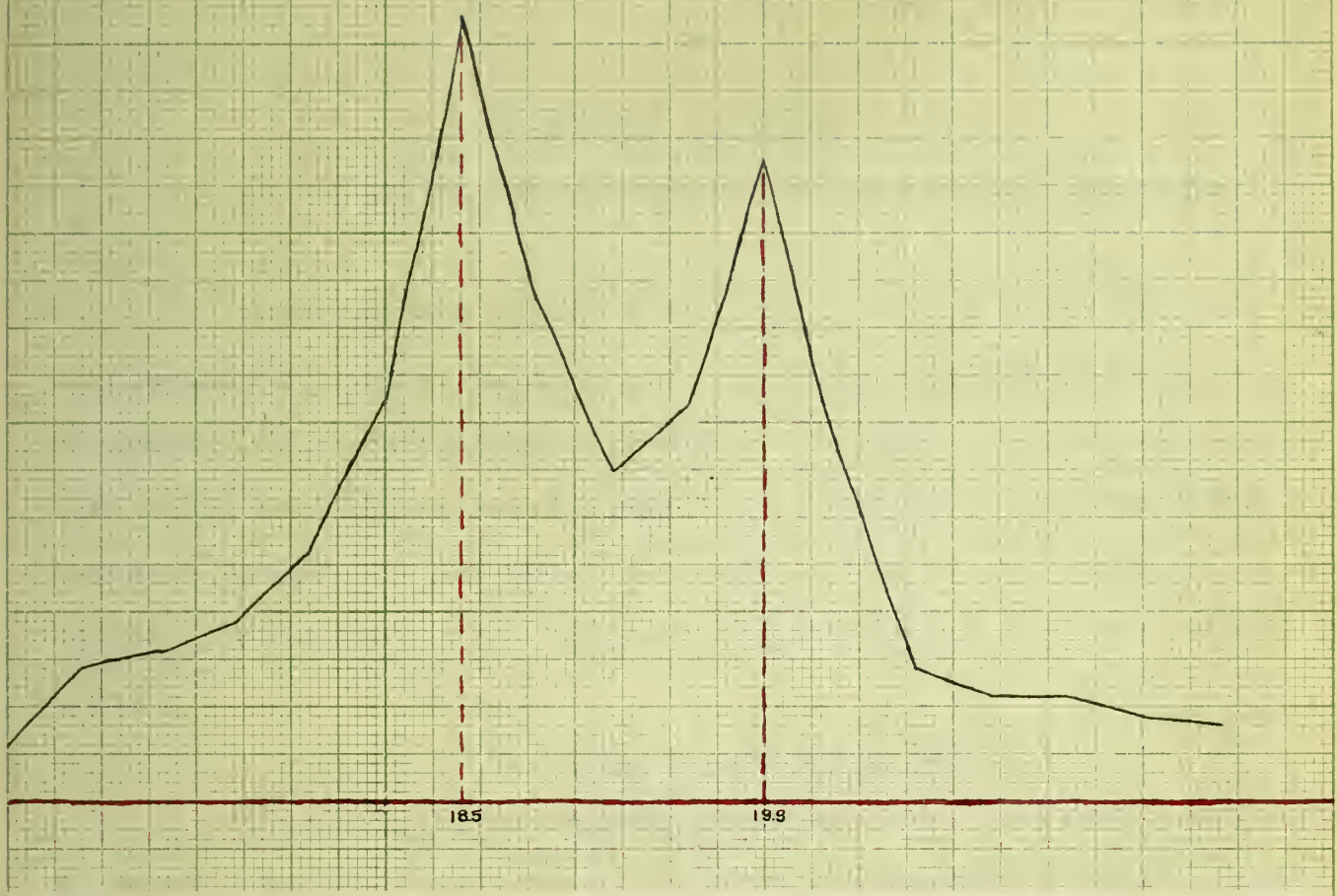
T. H. Montgomery (1906) states that this species has two kinds of spermatids. The male producers have seven normal chromosomes plus a "y" chromosome and the female producers have seven normal chromosomes plus an "x" chromosome. This places the insect in Type II. Such figures as are given were useless for computing the probable head length ratio of the spermatozoa. This being a Pentatomid, the same expected ratio was taken for it that was used for Euschistus variolarius. Material was obtained in Urbana in early May. The mass of spermatozoa was uniformly active and took a good fixation. Five hundred measurements were made. One division of the ocular micrometer equals 1.717microns. The resulting curve shows well marked bimodality. The modes come at 18.5microns and 19.9 microns. The head length ratio is 18.5:19.9 = 1:1.075. The expected ratio is 1:1.05.

6. Passalus cornutus

No published data could be obtained for this form. Many varieties of beetles have been described by N. M. Stevens and others. All. of these have "sex" chromosomes of one or another of the described types; Nos. I and II predominating.

Material was obtained at Urbana in late March. The spermatozoa were uniformly active and made a very good preparation. Five hundred measurements were made. One division of the ocular micrometer scale equals 1.717 microns. The resulting curve tends towards unimodality. The slight projection at 12.4 may indicate

COSMOPEPLA CARNIFEX



5. Value in microns	16.5	16.8	17.2	17.5	17.9	18.2	18.5	
Frequency	6	14	16	19	26	42	83	
18.9	19.2	19.6	19.9	20.3	20.6	20.9	21.3	21.6
53	35	42	68	37	14	11	11	9
22.0								
8								

either asymmetry or bimodality. A definite mode occurs at 11.7 microns.

7. Berosus striatus

No published data is available for use in judging this form.

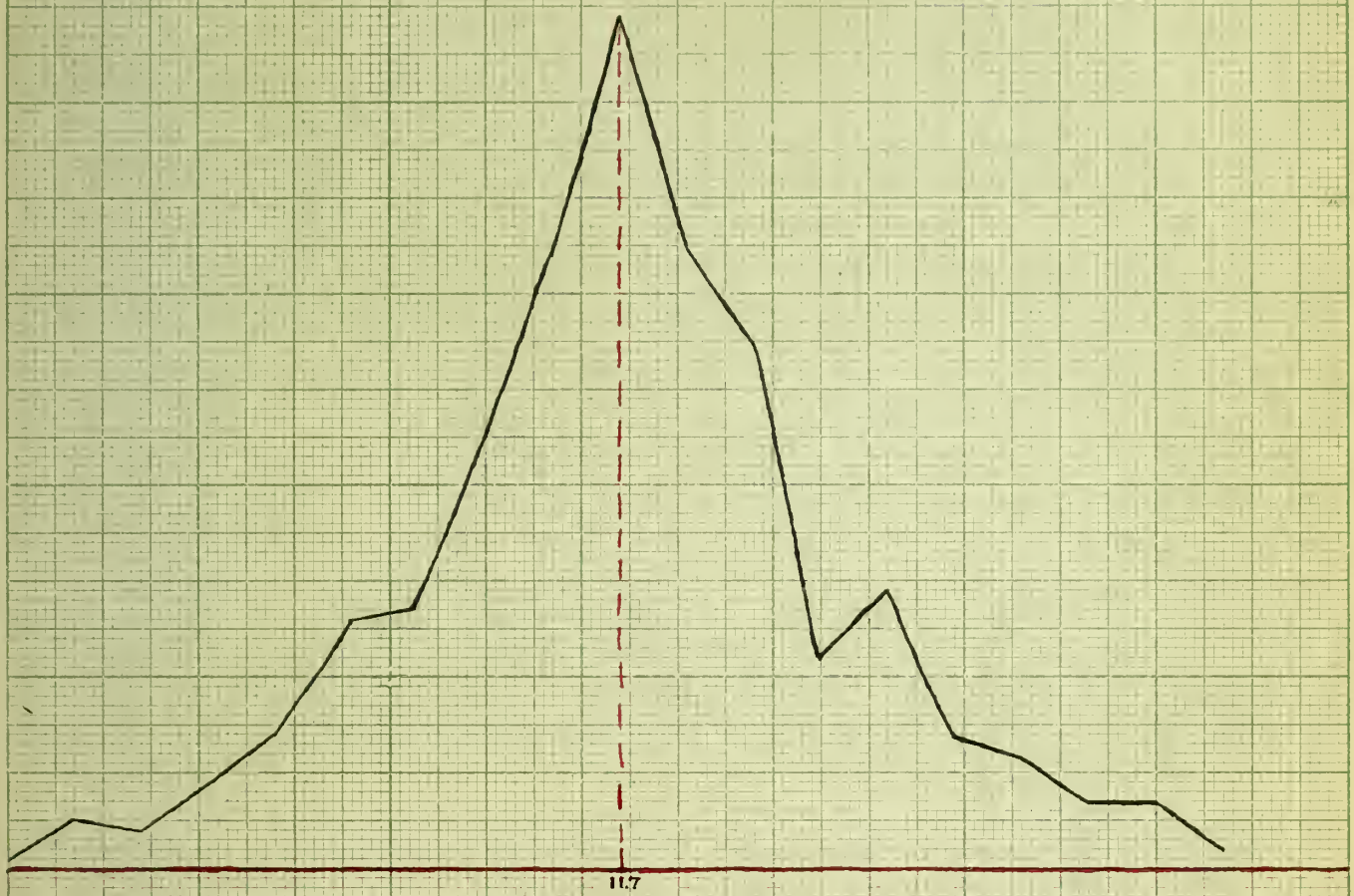
Material was obtained at Urbana in early April and gave bounteously of active spermatozoa. Straight spermheads were in profusion. Five hundred measurements were made. One division of the ocular micrometer scale equals 1.717 microns. The resulting curve is distinctly bimodal. The modes occur at 16.1 microns and 17.2. The sperm head length ratio is then 16.1:17.2 = 1.00 : 1.07.

8. Heliodrilus caliginosa

This species is very interesting as it is hermaphroditic. No doubt many zoologists would say without hesitation that a curve of the head lengths of its spermatozoa would be unimodal. Unfortunately no published data giving a clear account of the spermatogenesis of the earth worm could be obtained.

Material was obtained at Urbana in April. Plenty of functional spermatozoa were taken from the sperm ducts. The prepared slides were not of the best quality as the sperm head outlines were not uniformly distinct and tended to distortion. Only the best ones were measured. Five hundred measurements were made. One division of the ocular micrometer equals 1.717 microns. The plotted curve is flat topped. This would seem indicate bimodality, but may be due to an insufficient number of measurements.

PASSALUS CORNUTUS.



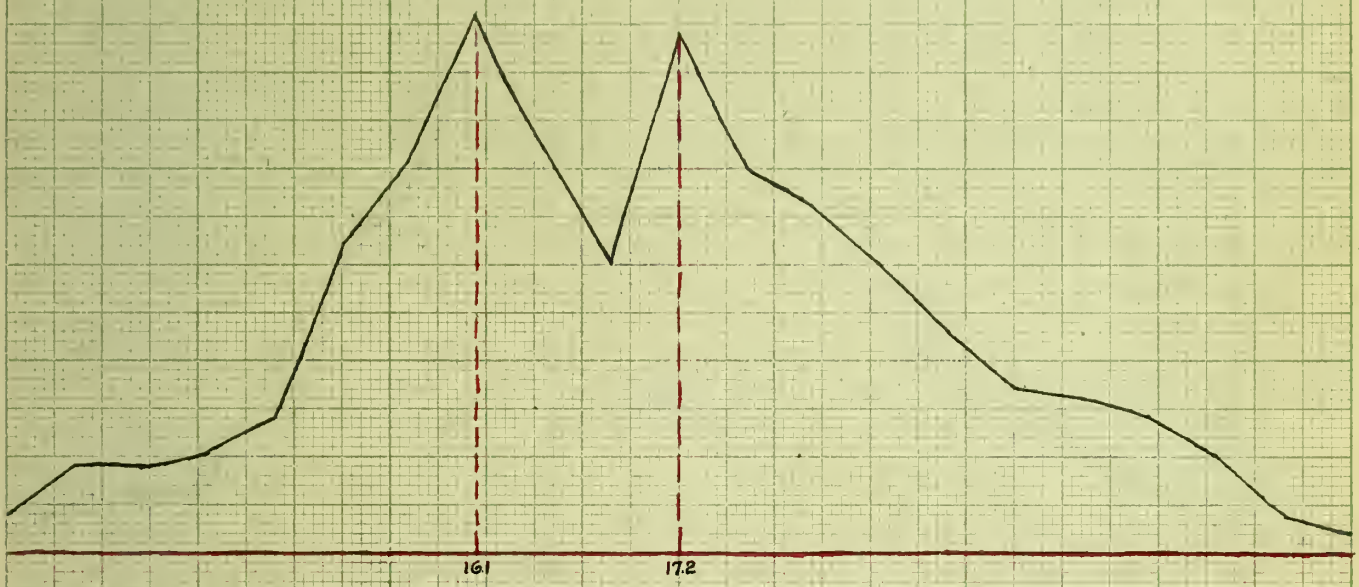
6.

Value in microns	10.15	10.3	10.45	10.6	10.8	11.0	11.15
Frequency	1	5	4	9	14	26	27

11.3	11.5	11.7	11.85	12.0	12.2	12.4	12.55	12.7
46	65	89	65	55	22	29	14	12

12.85	13	13.2
7	7	2

BEROSUS STRIATUS.



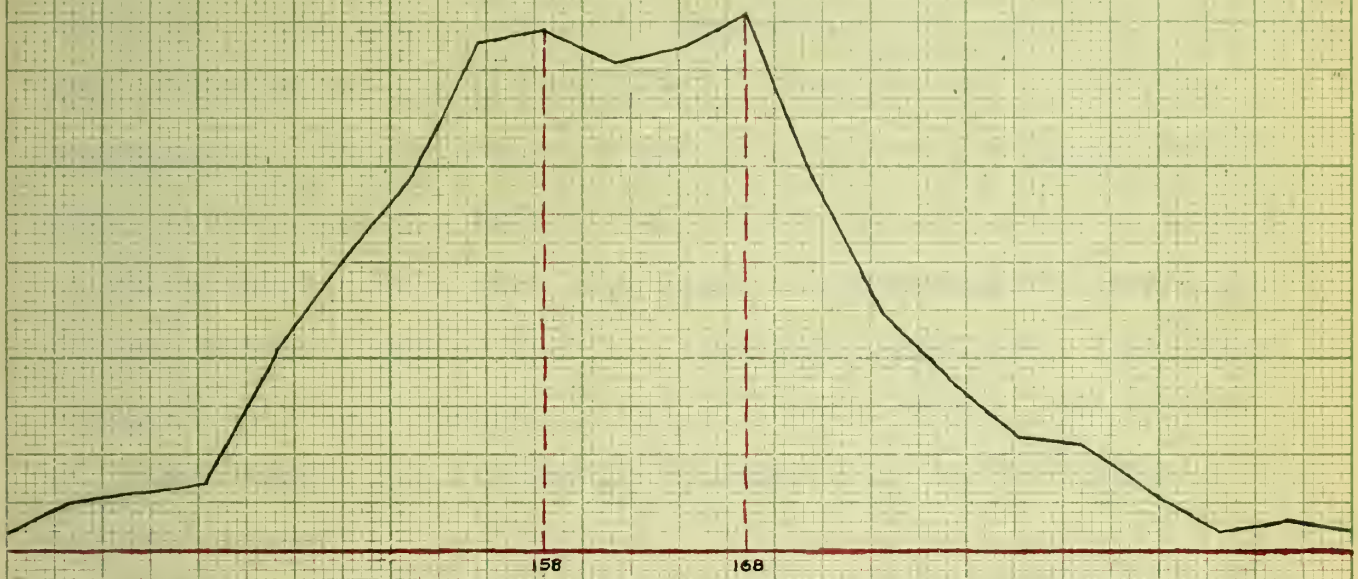
7.

Value in microns	13.7	14.1	14.4	14.7	15.1	15.5	15.8
Frequency	4	9	9	10	14	32	41

16.1	16.5	16.8	17.2	17.5	17.9	18.2	18.5	18.9
56	42	30	54	40	36	30	23	17

19.2	19.6	19.9	20.3	20.6
16	14	10	4	2

HELIODRILUS CALIGINOSA



8. Value in microns 13.0 13.4 13.7 14.1 14.4 14.7 15.1
Frequency 2 5 6 7 21 30 39

15.5 15.8 16.1 16.5 16.8 17.2 17.5 17.9 18.2
53 54 51 53 56 39 25 18 12

18.5 18.9 19.2 19.6 19.9
11 6 2 3 2

IV. DISCUSSION

While there has been written, in the past few years, a vast number of articles dealing with spermatogenesis and tracing "sex" chromosomes as far as the spermatid stage of their existence, there have been few attempts to demonstrate the effect of this unequal division, of the spermatogonial chromatin mass, upon the spermatozoa. Nearly a hundred articles a year are being written about spermatogenesis and yet only three papers have been published in which actual tests have been made of spermatozoan dimorphism. Yet the actual proof of the "x" chromosome hypothesis rests upon recognition of differences in spermatozoan lengths, separation of these lengths and artificial impregnation with the uniform derived product.

Dr. Charles Zeleny amd Mr. E. Carrol Faust first recognized the possibility of measuring dimorphism of spermatozoa and introduced their problem by a preliminary paper on Anasa tristis in 1913. This was followed by a large list of determinations in 1915. J. E. Wodsedalek (1913) measured dimorphism in the spermatozoa of the pig.

There is practically uniform agreement that there is dimorphism of spermatozoa, yielding female and male producing individuals. The ones with the larger chromatin content are commonly acknowledged to be the female producers. Inasmuch as the members of each group of this double spermatozoan population exhibit a wide range of head lengths, the two groups must necessarily overlap and significant results in fertilization can only be obtained

by taking individuals of the extreme sizes.

The data in the papers of Zeleny, Faust and Wodsedalek shows an expected bimodality in curves plotted from spermatozoan head lengths, The data included in this paper agrees with that of the above authors. The total accumulation of data includes some twenty three different species and its very extent banishes the possibility of obtained dimorphisms being due to any of the recognized sources of error.

Six of the forms dealt with in this paper give undeniable evidence of dimorphism of their spermatozoa. The seventh, Passalus cornutus, seems to be unimodal and the eighth, Heliodrilus caliginosa, gives a difficultly interpretable curve.

Passalus cornutus might be expected to exhibit bimodality inasmuch as there are a great number of beetles having "sex" chromosomes and practically none which may be definitely classed as being without them. However, the plotted curve is unimodal in character. This may arise in several ways. There may be only one kind of spermatozoa. This seems to be improbable in light of various cytological studies on beetle spermatogenesis. There may be two kinds of spermatozoa formed, one of which degenerates soon after formation. Morgan found this condition to exist in the aphids and it has been reported in the spiders. There may be two kinds of spermatozoa, the modes of which are so close together that the combined curve appears unimodal. This is the most probable explanation. In this form the modes might conceivably be at 11.5 microns and 11.85 microns and be practically

equal in height. The number of individuals of 11.7 microns for each group might be 3/4 of the number at the mode. The combined number of individuals of 11.7 microns in length would be 1 1/2 times the number at each true mode and a false mode would be created.

Heliodrilus caliginosa is an hermaphrodite. Few accounts of hermaphrodite spermatogenesis are to be found but such authors as have published data upon the subject seem to uphold the view that two kinds of spermatids are formed. Zarnik (1913) traced the spermatogenesis of a parthenogenetic mollusc, Creseis aricula. He found that two kinds of spermatozoa were formed, one of which was either nonfunctional or else degenerated. Schleip (1913) believes that the spermatogenesis of parthenogenetic species is the same as that of two sexed species. He thinks that sex is confined to the sex organs and that the somatic cells are neutral in regards to sex.

Boveri, Kreiger, and Gulick, have also investigated the spermatogenesis of parthenogenetic forms, Their concensus of opinion seems to be that two kinds of spermatids are produced. It will be seen that there are several ways in which spermatogenesis may develop in parthenogenetic individuals. Two kinds of spermatozoa may be formed one of which is either not functional or else degenerates. Two kinds of functional spermatozoa may be generated. One kind ofspermatozoa may be formed. The curve obtained is flat-topped. This indicates bimodality. The modes probably come at 15.8 and 16.8 giving a ratio of 1:1.06.

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T A B L E

A summarized statement of the results obtained in measuring the spermatozoan head length of eight species of Hemiptera, Coleoptera and Annelida

Name	Figure	No. of spermatozoa	Lower mode in microns	Upper mode in microns	Observed ratio	Expected Ratio
Anasa tristis						1:1.11
Leptocoris trivittatus	2	984	25.1	27.8	1:1.09	
Corizus lateralus	4a	500	27.1	29.5	1:1.09	
	b	500	27.1	29.5	1:1.09	
Reduviolus ferus	3	500	27.4	28.8	1:1.05	
Euschistus variolarius	5	500	15.1	16.5	1:1.09	1:1.05
Cosmopepla carnifex	6	500	18.5	19.9	1:1.075	
Pyrrochoris apteris						1:1.08
Passalus cornutus	7	500				
Berosus striatus	8	500	16.1	17.2	1:1.07	
Heliodrilus caliginosa	9	500	15.8	16.8	1:1.06	

V. SUMMARY

1. Cytological evidence accumulated by the leading zoologists of the day shows that animals produce two kinds of spermatids differing in chromatin content, this difference probably determining the sex of the fertilized egg.

2. This hypothesis must be tested by measurement of dimorphism of the spermatozoa, separation of the two kinds and artificial impregnation with the uniform product.

3. Since the spermatids receive different amounts of chromatin, the spermatozoa must differ in size as they are almost entirely composed of chromatin.

4. It is the object of this paper to demonstrate head length differences in spermatozoa from single testes of the chosen species.

5. Large range of variation was found in each case and the size groups could only be made definite by a large number of measurements and a plot of their size distribution.

6. Five hundred measurements was decided on as the minimum number to be used.

7. The general result was a bimodal or two pointed curve indicating the presence of two populations.

8. Wherever possible the ratio of these two modes was compared with a ratio calculated from published figures of chromosomes of the species.

9. The general conclusion is that there are two size groups in spermatozoa of a majority of animal species. This size difference is correlated with a difference in chromatin content.

10. According to cytological evidence the larger spermatozoa are female producing and the smaller are male producing.

11. The accumulated mass of data tends to eliminate the possibility of the obtained results being due to any one of the listed sources of error.

12. Leptocoris trivittatus. The observed ratio is 1:1.09.

13. Reduviolus ferus. The observed ratio if 1:1.05.

14. Corizus lateralus. The observed ratio is 1:1.09.

15. Euschistus variolarius. The calculated ratio is 1:1.04. The observed ratio is 1:1.09.

16. Cosmopepla carnifex. The observed ratio is 1:1.075.

17. Passalus cornutus. No observed bimodality.

18. Berosus striatus. The observed ratio is 1.00:1.07.

19. Heliodrilus caliginosa. The observed ratio is 1.00:1.06.

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